

STANDARD TIME AND FREQUENCY DISSEMINATION VIA EGYPTIAN DIGITAL SATELLITE

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Abstract

The Egyptian Satellite Company and the National Institute for Standards (NIS) in Egypt, with technical assistance from the National Institute of Standards and Technology (NIST) in the United States, are collaborating to broadcast frequency and time information to North Africa and the Middle East Region from a Nilesat geostationary satellite. The Nilesat Direct-to-Home broadcasts of television and radio programs include a Time and Frequency broadcast, enabling users to recover traceable Time and Frequency with existing antenna and receiver technology. The broadcast includes a stabilized reference carrier frequency, a modified IRIG – B time-code, and an audible time-of-day announcement. This paper discusses the architecture and scope of this system.

INTRODUCTION

NILESAT, the Egyptian Satellite Company, placed a geostationary satellite in orbit in April of 1998 to provide Direct-to-Home broadcasting services to North Africa and the Middle East. The broadcast

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includes television, radio, and data channels received on a 30-cm dish antenna and commercially available receiver sets. The Egyptian National Institute for Standards (NIS) has negotiated with NILESAT for the use of a single radio channel on the satellite platform for the dissemination of traceable time and frequency information. The Time and Frequency Division at the National Institute of Standards and Technology (NIST) in the United States is acting as a technical consultant through a grant from the US-Egypt Joint Science and Technology Program. The 15 kHz bandwidth FM radio channel contains a modified IRIG-B (Inter-Range Instrumentation Group) time code on one side of the frequency modulation and an audible seconds pulse and a top of the minute voice announcement, in Arabic, on the other side. NIST designed and built the Time Code Generator (TCG) that produces the two signal channels. The TCG is supplied a 1 pps time signal from a cesium atomic clock that is synchronized with UTC (NIS) to provide time traceability. Frequency traceability will be derived from the IRIG time code carrier frequency by use of a triangulation of monitoring stations that report their location and frequency offset in near real time via the Internet. Monitoring the frequency offset of the device under test at a known location and computing a set of orbital equations using the published Internet information can thus achieve frequency calibration. A code-only TCG was installed at the NILESAT uplink facility in December 2006 and tested for code reception. A code and voice capable TCG was installed in September 2007 and is currently under test.

THE EGYPTIAN NILESAT SYSTEM

The NILESAT 101 geostationary satellite is located at 7° west longitude with an uplink frequency band of 17.3 to 17.7 GHz and a downlink frequency band of 11.7 to 12.1 GHz. There are 12 transponders, each of 33 MHz bandwidth. The effective isotropic radiated power (EIRP) is shown in Figure 1, with a maximum EIRP of 50.5 dBW. Table 1 shows the EIRP for several locations across the region. The NILESAT broadcast is a Direct-to-Home service, which provides Digital Video Broadcasting (DVB), audio broadcasting, and high-speed data services [1].

TIME DISSEMINATION

The basic layout for the dissemination system is shown in Figure 2. The NILESAT uplink facility is located 30 km from NIS in the 6th of October City. At the uplink, a cesium oscillator is used as the 1 pps source for the TCG. The cesium oscillator is synchronized to the NIS Time and Frequency laboratory Time Scale through a GPS common view link, assuring traceability. The TCG feeds the NILESAT uplink two signals into the FM radio channel. The left channel is fed the modified IRIG-B time code, while the right channel is fed the audio portion of the generated signal. The NILESAT broadcast is received at the NIS laboratory for monitoring purposes. The time information at the NILESAT facility is advanced to allow the On-Time-Mark received at the NIS laboratory to be within 10 ms. The advancement is necessary to compensate for transmission and equipment delays. The total system delay is approximately 794 ms [2].

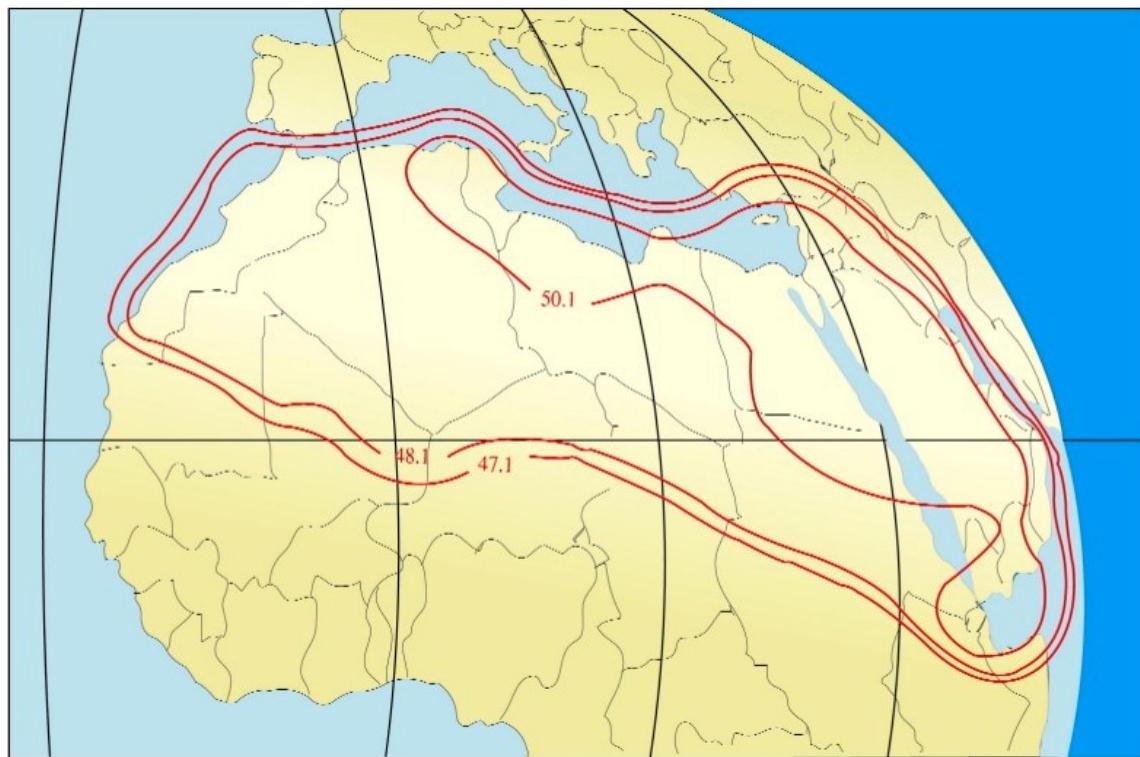


Figure 1. EIRP contour map for NILESAT 101 satellite.

Table 1. List of major cities within coverage area and their respective EIRP values.

City	EIRP (dBW)	City	EIRP (dBW)
Cairo	50.5	Doha	49.2
Alexandria	50.3	Muscat	48.0
Aswan	50.2	Abu-Dhabi	48.9
Beirut	50.2	Aden	50.3
Damascus	50.3	Casablanca	47.7
Amman	50.3	Marrakech	47.7
Riyadh	50.3	Algiers	47.3
Mecca	50.1	Tunis	50.2
Kuwait	50.3	Tripoli	50.2
Manama	49.2	Khartoum	48.2
Baghdad	48.2	Nawakshut	47.2
Mogadishu	47.2	Jerusalem	50.2
Djibouti	48.2	Gaza	50.2

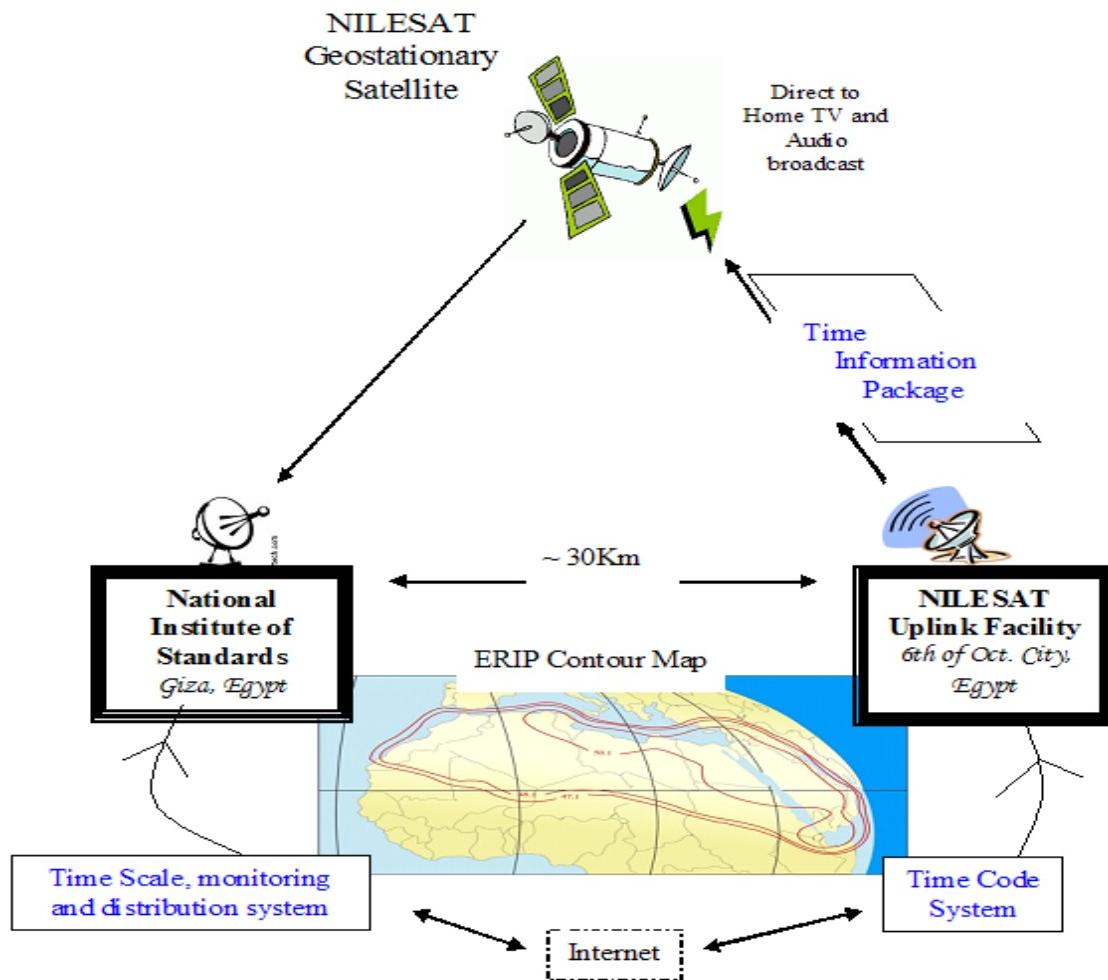


Figure 2. Diagram of dissemination system.

TIME CODE GENERATOR

The NIS Time Code Generator (TCG) was built by NIST engineers to generate two signals. The first signal is a modified IRIG-B time code. The IRIG-B time code is a 1 kHz carrier frequency signal that is amplitude modulated at 10 ms intervals in a binary coded decimal (BCD) format. The BCD weighting scheme is 1-2-4-8, with the least significant bit sent first [3]. The basic IRIG-B time code is shown in Figure 3.

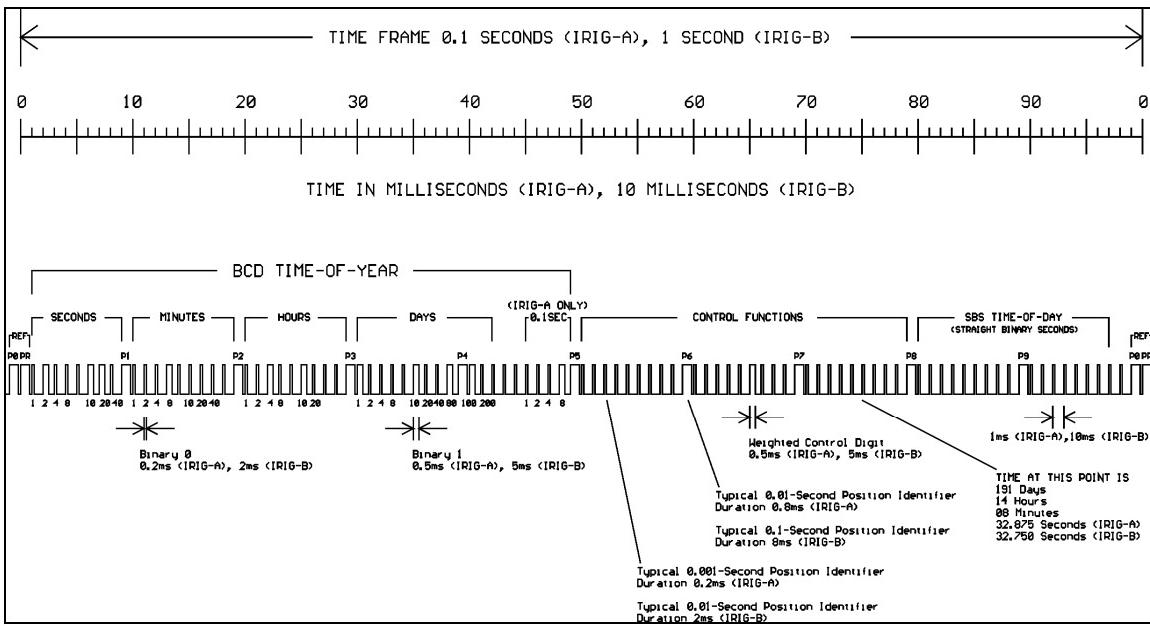


Figure 3. The Standard IRIG time code format.

The IRIG-B time code has been modified to include Daylight Saving and UT1 correction information. The code has been further modified to include Leap Year and Leap Second warning flags. Code bits 73 and 74 are used to encode Daylight Saving information. When Standard Time is in effect, bits 73 and 74 are set to 0. On the day of a change from Standard Time to Daylight Saving Time, bit 73 changes from 0 to 1 at 0 hour UTC, and 24 hours later, bit 74 changes from 0 to 1. On the day of the change back to Standard Time, bit 73 changes from 1 to 0 at 0 hour UTC, and bit 74 changes from a 1 to a 0 exactly 24 hours later. Bits 61 through 63 and 66 through 69 are used to indicate UT1 correction information. The bits 61, 62, and 63 show whether UT1 is positive or negative with respect to UTC. If bits 61 and 63 are a 1, the UT1 correction is positive. If bit 62 is a 1, then the UT1 correction is negative. Bits 66 through 69 form a four-bit BCD group that indicates the magnitude of the correction in units of 0.1 s. Bit 71 and 72 are used to encode the Leap Year and Leap Second warning flags respectively. If bit 71 is set to a 1, the current year is a Leap Year. The bit is set to 1 during each Leap Year after 1 January, but prior to 29 February. It is set back to 0 on 1 January of the following year. If bit 72 is set to a 1, a Leap Second will be added at the end of that month. The bit is set to 1 near the start of that month and reset to 0 following the insertion of the Leap Second.

The second signal is an audio time signal. It consists of “seconds” indicator tone bursts from seconds 1–29 and 31–45 of 100-ms duration. There is also a 250-ms tone burst at the top of each minute. From seconds 46–59, there is a recorded voice announcement in Arabic stating the hour and minute of the next top-of-the-minute tone burst. The voice states “At the sound of the tone, the time will be” stated hour and minute “Egyptian Local Time.”

Figure 4 shows a block diagram of the Time Code Generator. The cesium oscillator is used as a stable reference frequency for the TCG. The device uses three PIC micro-controllers. One controller is used to generate the IRIG-B time code. Another controller is used to record and plays back the time-ticks and the top-of-minute voice announcements. These two operations are kept synchronized through an I²C bus. A third microcontroller interfaces the user to these operations.

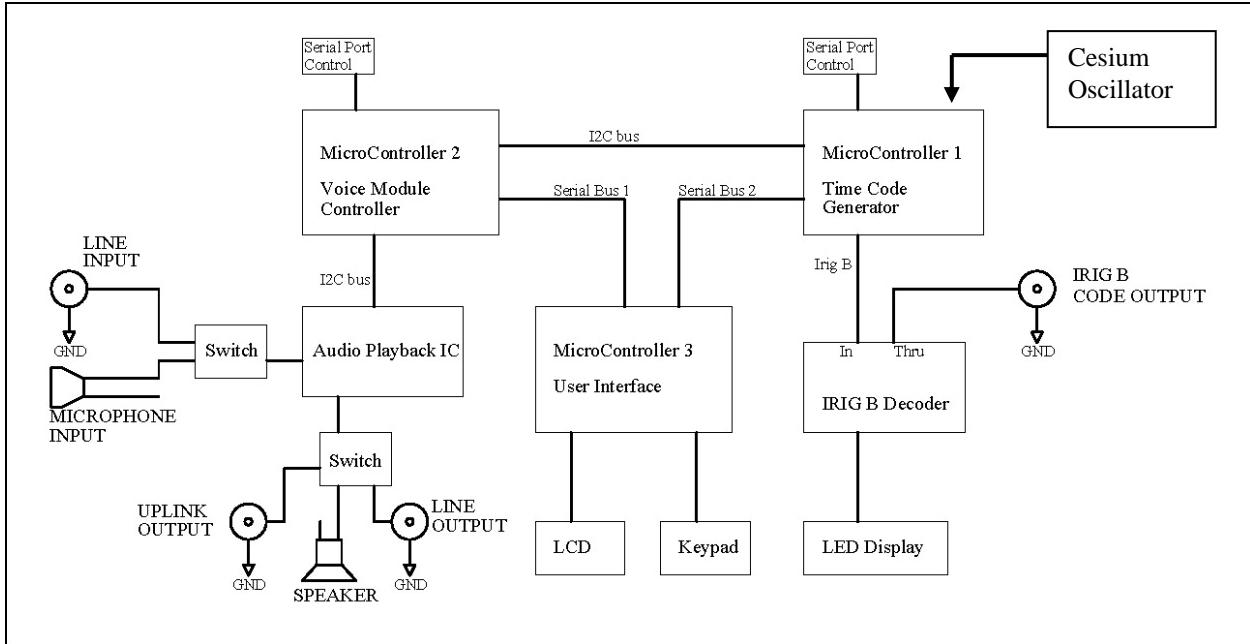


Figure 4. Block diagram of NIS Time Code Generator.

FREQUENCY DISSEMINATION

The IRIG-B time code is generated by use of a 1 kHz carrier frequency. This frequency can be used as a standard reference for calibration purposes. The 1 kHz signal is initially stabilized in the Time Code Generator by the cesium oscillator. However, this stability is reduced in the received carrier due to Doppler shifting as the satellite moves in its orbit. NILESAT maintains the position of the satellite within an orbital range of $\pm 0.09^\circ$ East to West and $\pm 0.07^\circ$ North to South. Within this range, the satellite has a diurnal movement in a figure-eight pattern. Figure 5 is a stability plot of the received carrier frequency over a 7-day period. The diurnal frequency shifts are clearly evident. Other satellite dissemination services compensate for this stability degradation by modeling the satellite movement and computationally removing the frequency shifts [4]. This method improves the calibration stability; however, it requires frequent updates of the satellite's ephemeris to maintain proper corrections.

We propose a new technique to improve the frequency calibration capability of this service. Several monitoring sites can be established in the region. These sites must be widely separated within the reception region, as illustrated in Figure 6. Each monitoring site would compare the received carrier frequency to a stable local oscillator. The comparison results would then be published on the Internet in near real time, along with the monitoring site's exact location. At the calibration site, the received carrier frequency is compared to the oscillator to be calibrated. By computing a set of orbital equations using the data from the monitoring sites, the frequency shifts can theoretically be removed from the calibration. The orbital equations must also compensate for the relativistic effects of the moving system. This may require up to six monitoring stations for proper compensation. This method is presently being investigated and will be reported on at a later date.

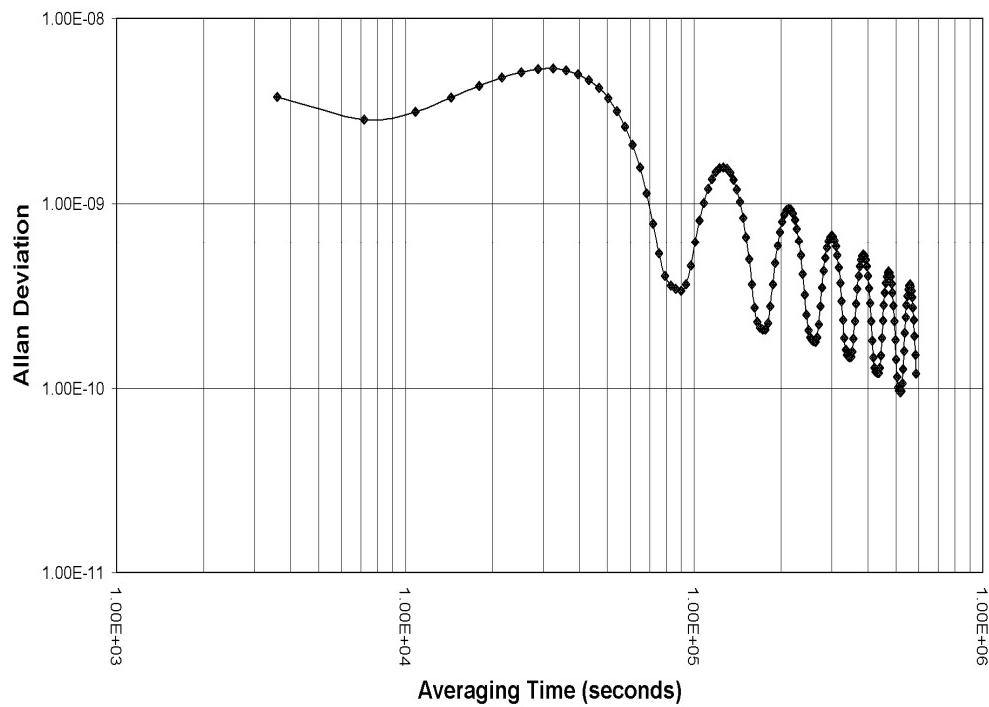


Figure 5. Stability plot of received code carrier frequency.

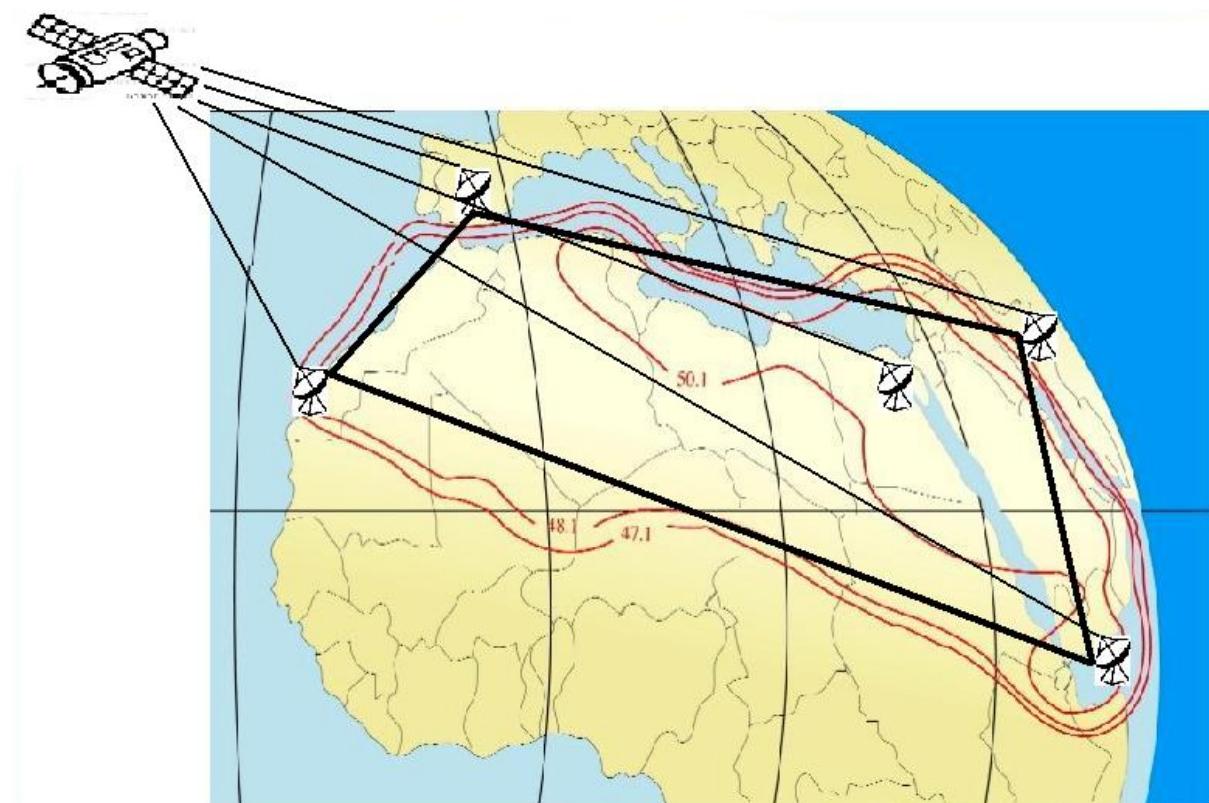


Figure 6. Monitoring station locations for wide area coverage.

CONCLUSIONS

Through a collaborative effort of the Egyptian National Institute for Standards, the U.S.A.'s National Institute of Standards and Technology, and the Egyptian Satellite Company, NILESAT, a new satellite-based Time and Frequency dissemination service has been created. The service provides traceable time and frequency information from NIS to the North African and Middle Eastern region by use of commercially available receiving equipment. Time-of-day information can be received by decoding a standard time code format or by simply listening to the audio broadcast. Frequency calibration is possible by comparing an oscillator to the received code carrier frequency, and then removing the satellite Doppler errors by comparing to near-real-time Internet published information, provided by monitoring stations.

This paper is a contribution of the United States government and is not subject to copyright.

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